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REDUCTION OF QUANTIZATION NOISE IN PCM SPEECH CODING.(U)

MAY 79 J S LIM, A V OPPENHEIM F19628-78-C-0002

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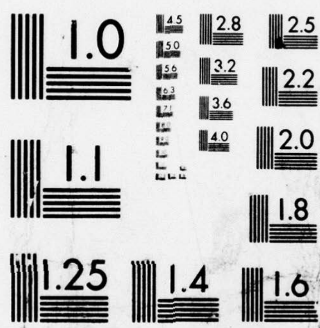

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REDUCTION OF QUANTIZATION NOISE IN PCM SPEECH CODING

J. S. LIM
Group 27

A. V. OPPENHEIM
Division 2

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ABSTRACT

A new technique to reduce the effect of quantization noise in PCM speech coding is proposed. The procedure consists of using dither noise to ensure that the quantization errors can be modelled as additive signal independent noise and then reducing this noise through the use of a noise reduction system. The procedure is illustrated with examples.

I. Introduction

Wideband speech coding systems typically rely on general waveform coding techniques (1,2) such as instantaneous quantization (PCM) for which the step size is fixed, any of a variety of forms of adaptive quantization, and differential schemes such as delta modulation, adaptive delta modulation, continuously variable slope delta modulation, etc. Instantaneous quantization with fixed step sizes has the advantage that the quantizer and coder are particularly straightforward although as the step size increases the quantization effects become severe. In this note we propose a new technique for reducing the effect of quantization noise in PCM speech coding. As described in Section II, the procedure consists of using dither noise to ensure that the quantization errors can be modelled as additive signal independent noise and then reducing this noise through the use of any of a variety of noise reduction systems. The procedure is illustrated in Section III.

II. Procedure for Quantization Noise Reduction

For linear quantization, in which the step sizes are fixed and equal, if the input signal fluctuates sufficiently and if the quantization step size is small enough, the quantization error can be modelled as additive uniformly distributed white noise that is statistically uncorrelated with the signal.(3) When the step size becomes sufficiently large, the quantization error becomes signal dependent. For such cases, however, it is well known (4,5,6) that through the use of "dither" noise, as illustrated in Figure 1, the quantization error can be replaced by white noise which is uniformly distributed and statistically independent of the signal. In this system, z(n) is a pseudo-random, uniformly distributed, white noise sequence with the probability density function

$$p_{z(n)}(z) = \frac{1}{\Delta} \text{ for } -\frac{\Delta}{2} \leq z \leq \frac{\Delta}{2} \qquad (1)$$
$$0 \text{ otherwise}$$

where Δ is the quantizer step size. A similar technique (4) has been used in image processing to remove the contouring effect evident in uniform image quantization.

For nonuniform, fixed quantization with dither noise the quantizer can be represented conceptually in the form of Figure 2 where F[.] is a specified nonlinearity. In the implementation of a nonuniform quantizer in the form of Figure 2 the quantization effects are additive white noise prior to the nonlinearity $F^{-1}[.]$.

In this note we propose a system to reduce the effects of quantization noise for general nonuniform quantization systems of the form of Figure 2. The system exploits the fact that in the system of Figure 2, the quantization error is at an intermediate stage as additive, white, signal independent noise. Recently, a number of procedures have been proposed and developed for the enhancement of speech degraded by additive uncorrelated background noise. Our procedure for reducing the effects of quantization then corresponds to inserting a noise reduction system

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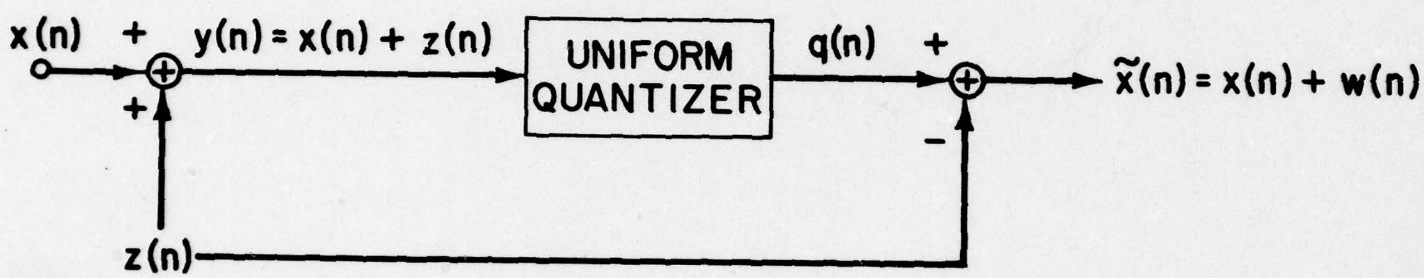

Fig. 1. System for decorrelating quantization errors in a uniform quantizer using pseudo-random noise.

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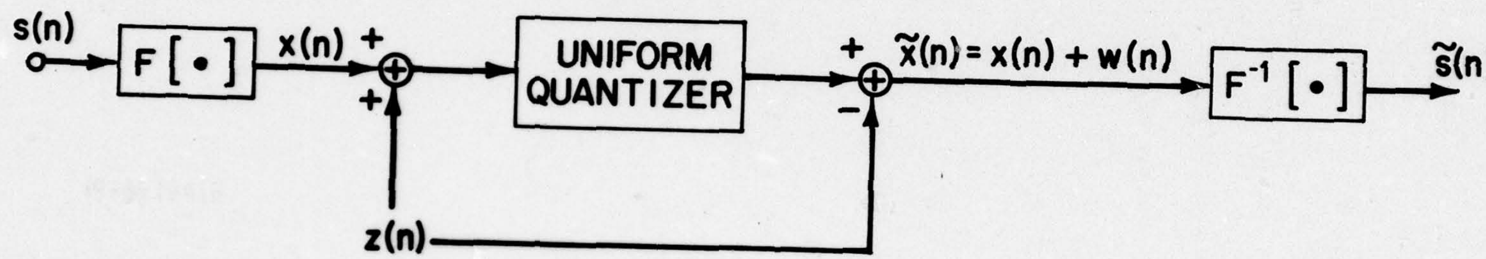

Fig. 2. System for decorrelating quantization errors in a non-uniform fixed level quantizer using pseudo-random noise.

into the system of Figure 2 as indicated in Figure 3. The sequences $\hat{x}(n)$ and $\hat{s}(n)$ in the figure represent an estimate of x(n) and s(n). A system similar to Figure 3 was considered by Lim [7] in reducing the quantization noise in the context of PCM image coding.

III. Examples

We illustrate the characteristics of the system of Figure 3 through an example in which uniform quantization is assumed so that the nonlinearity F[.] is eliminated. The noise reduction system used is the RLMAP (Revised Linearized Maximum A Posteriori Estimation) speech enhancement system (8,9).

In Figure 4(a) is shown a segment of noise-free voiced speech. In Figure 4(b) is shown the speech waveform of Figure 4(a) coded by a PCM system with a 2-bit uniform quantizer. The effect of quantization is quite visible in the stair-case shape of the waveform. In Figure 4(c) is shown the result of adding dither noise in a PCM system with a 2-bit uniform quantizer. In Figure 4(d) is shown the result obtained by applying the RLMAP speech enhancement system to the waveform in Figure 4(c).

Figures 5 and 6 illustrate the procedure as carried out on the sentence "line up at the screen door" spoken by a male speaker. In Figure 5(a) is shown the spectrogram of the original sentence. Figures 5(b),(c) and (d) correspond to spectrograms of the speech in Figure 5(a)

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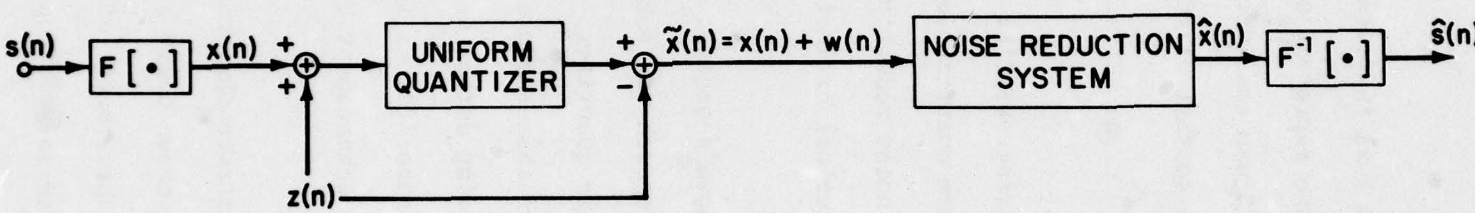

Fig. 3. A system for the reduction of quantization noise in PCM speech coding with a non-uniform fixed level quantizer.

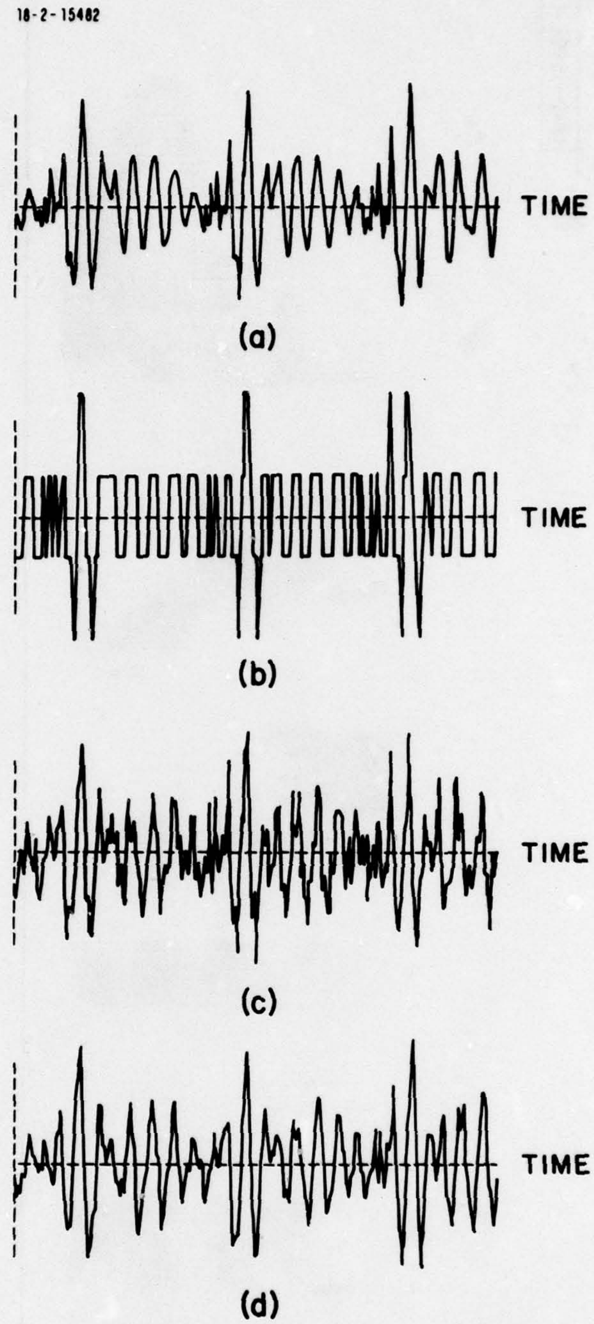

Fig. 4(a-d). a) A segment of voiced speech. b) Speech waveform of Fig. 4(a) coded by a PCM system with a 2-bit uniform quantizer. c) Results of using pseudo-random noise for the speech waveform of Fig. 4(a) in a PCM system with a 2-bit uniform quantizer. d) Result of application of a noise reduction system to the waveform of Fig. 4(c).

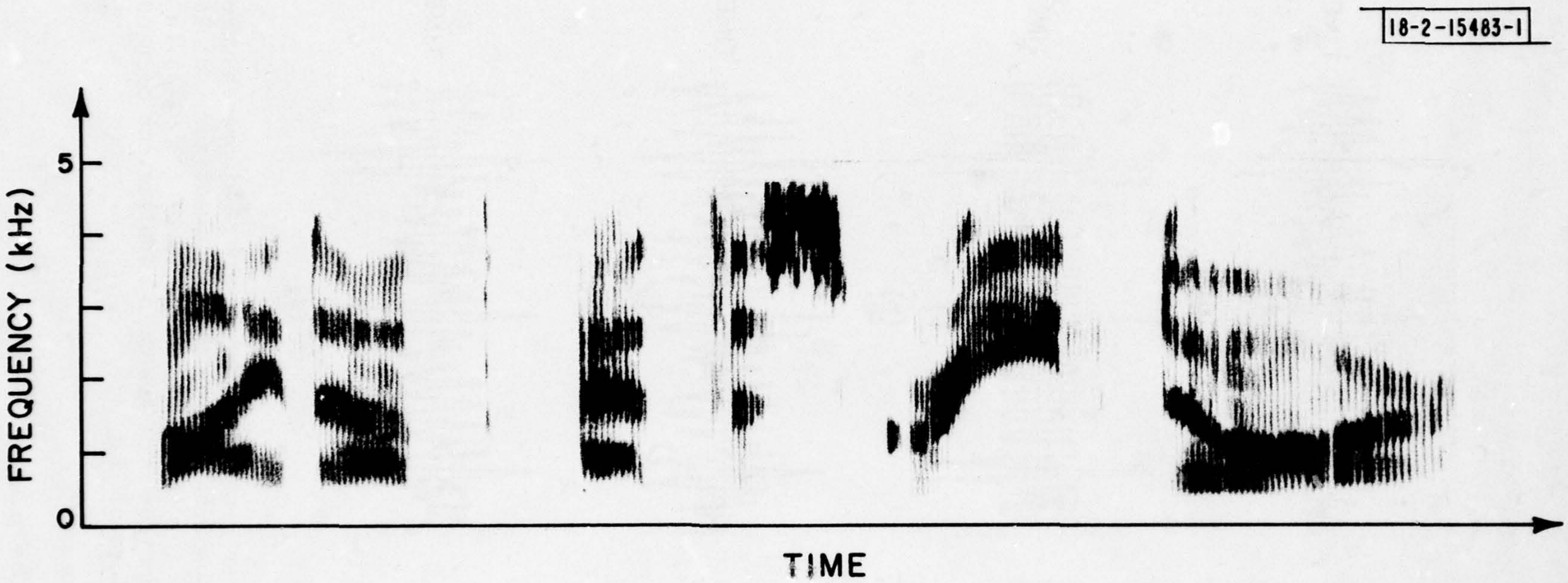

Fig. 5a. Spectrogram of an English sentence "line up at the screen door" spoken by a male speaker.

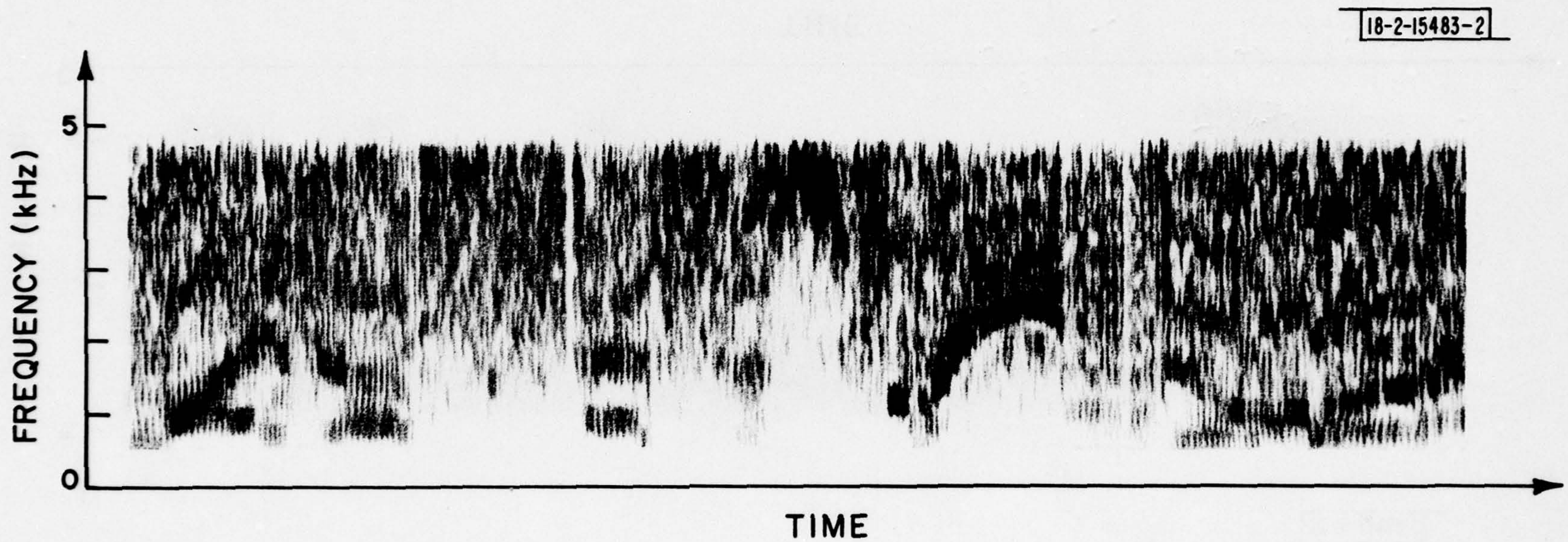

Fig. 5b. Spectrogram of speech in Fig. 5a. coded by a PCM system with a 2-bit uniform quantizer.

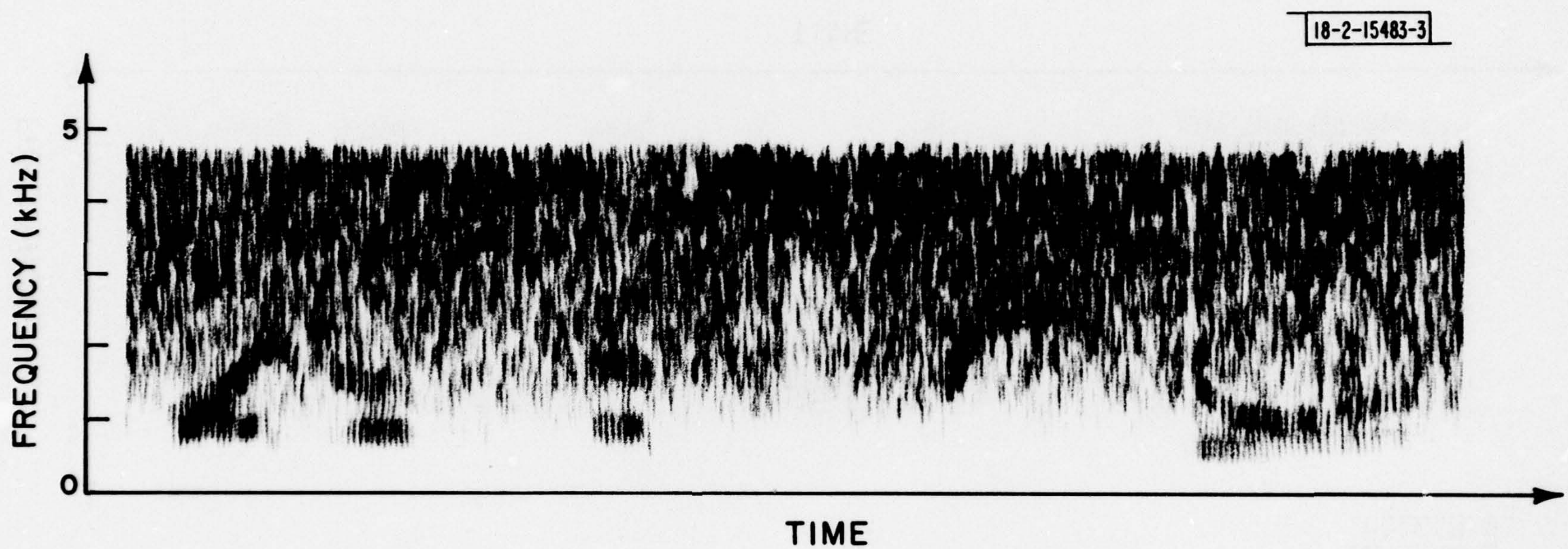

Fig. 5c. Spectrogram of speech in Fig. 5a. obtained by using pseudo-random noise in a PCM system with a 2-bit uniform quantizer.

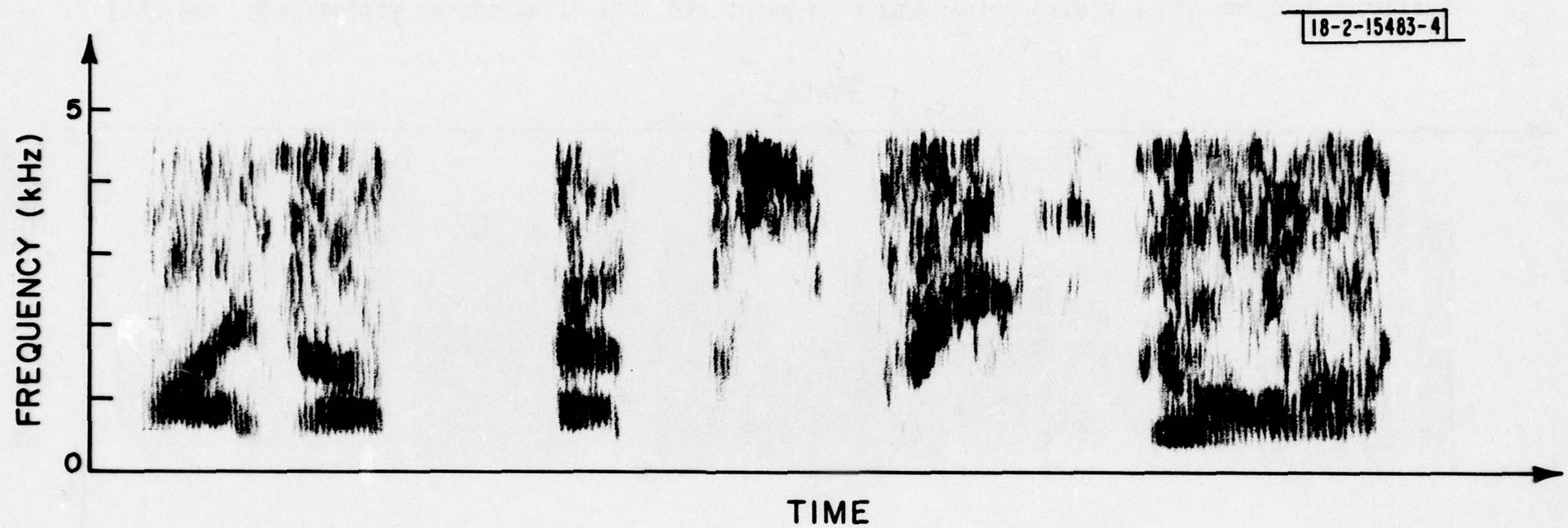

Fig. 5d. Spectrogram of speech obtained by applying a noise reduction system to speech in Fig. 5c.

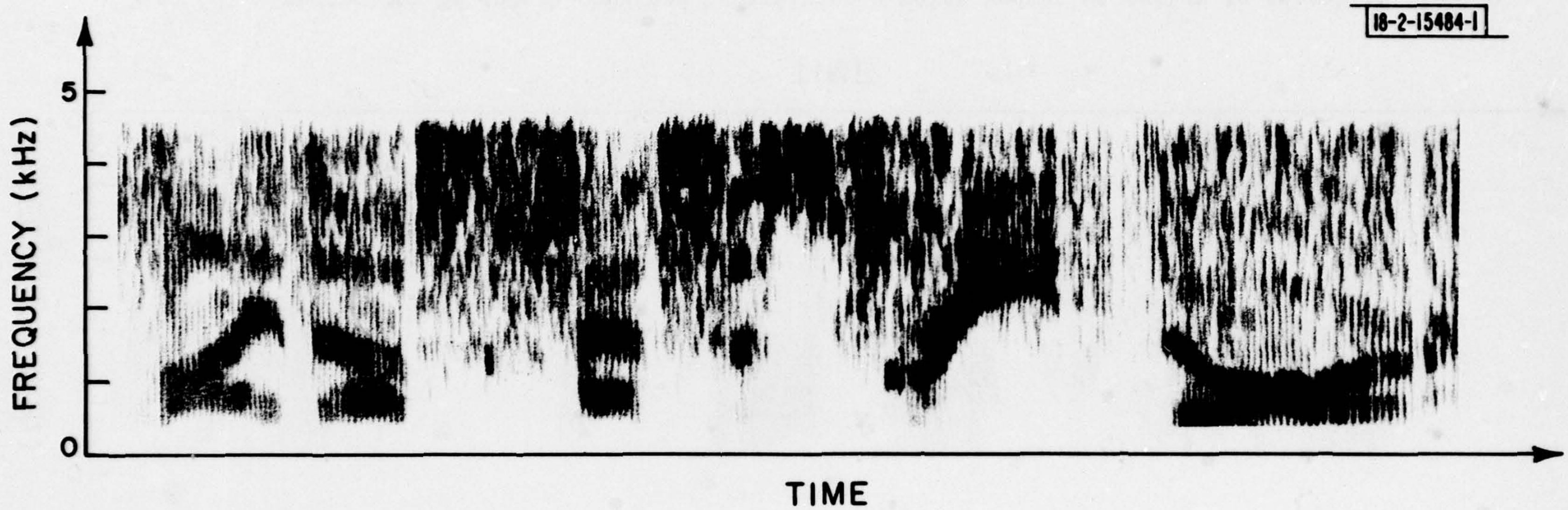

Fig. 6a. Spectrogram of speech in Fig. 5a. coded by a PCM system with a 4-bit uniform quantizer.

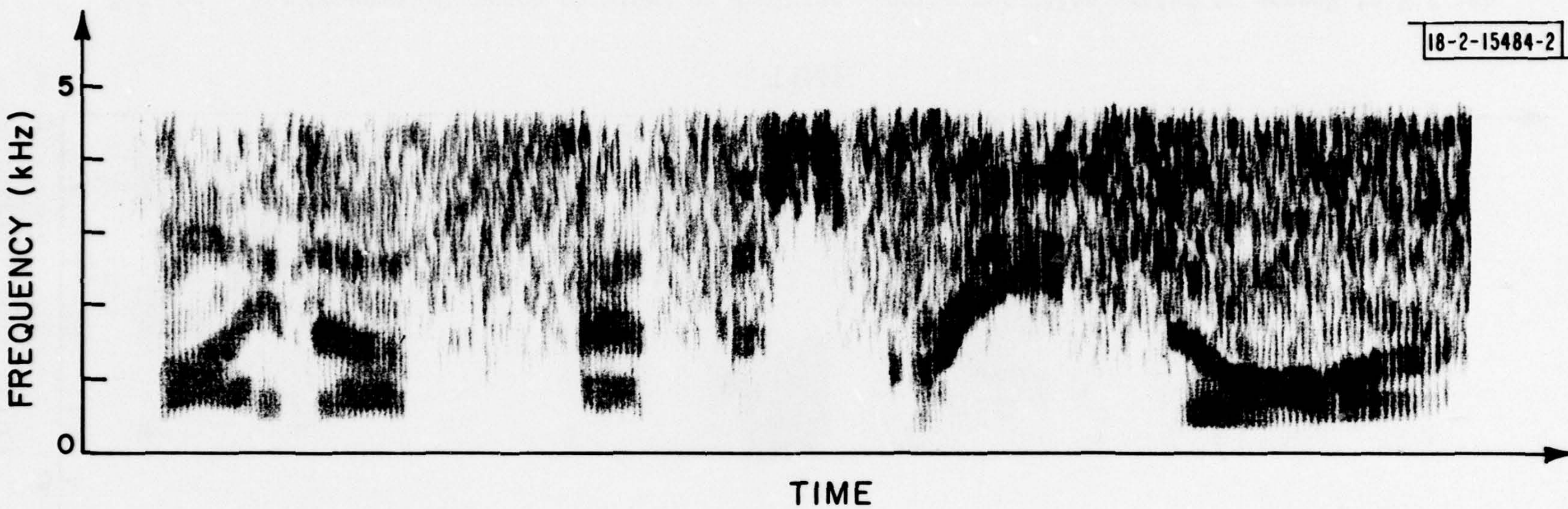

Fig. 6b. Spectrogram of speech in Fig. 5a. obtained by using pseudo-random noise in a PCM system with a 4-bit uniform quantizer.

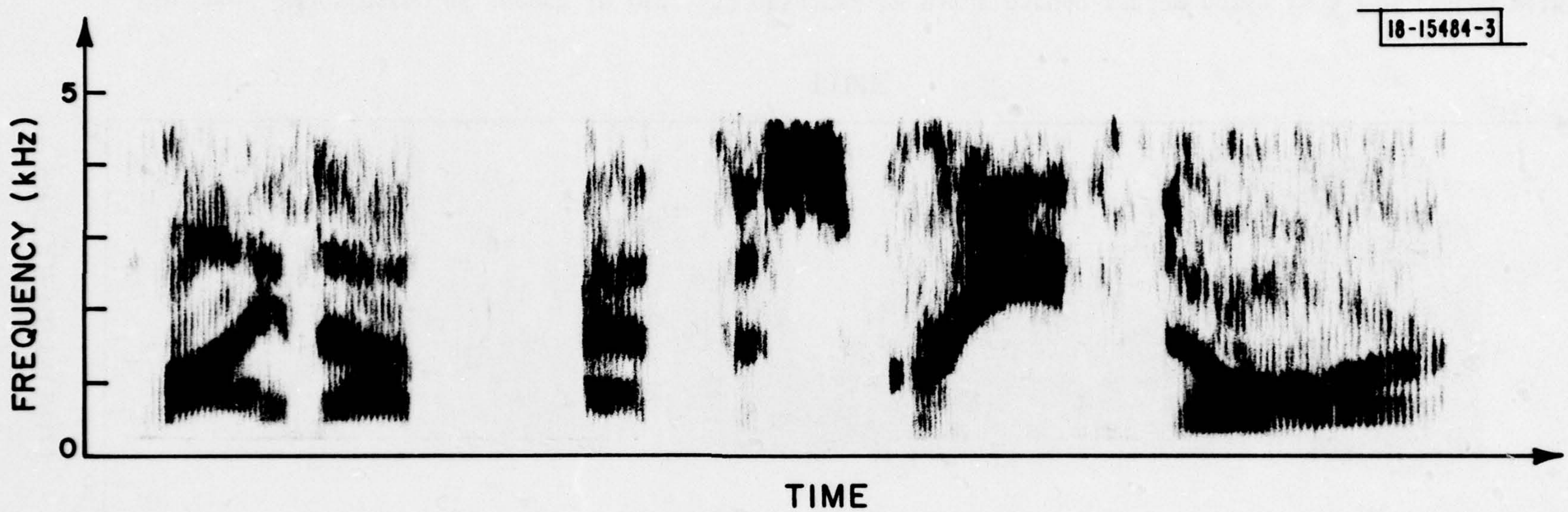

Fig. 6c. Spectrogram of speech obtained by applying a noise reduction system to speech in Fig. 6b.

based on PCM coding, PCM coding with dither noise, and PCM coding with dither noise followed by the RLMAP speech enhancement system respectively. The PCM coding system used in Figure 5 is again a 2-bit uniform quantizer. Figures 6(a), (b) and (c) are essentially the same as Figures 5(b), (c) and (d) with the difference that the PCM system used is a 4-bit uniform quantizer. It is clear from the examples that the quantization noise is noticeably reduced.

IV. Conclusions

In this note we have proposed a system for reducing the effects of quantization noise through the use of a noise reduction system. Preliminary examples support the basic hypothesis and are extremely encouraging. While the basis for the procedure is associated with fixed, nonuniform quantization it is speculated that it can be generalized to other quantization schemes such as differential quantization. Furthermore it is well known that in speech enhancement systems, there is potential benefit if the undegraded speech signal is available for preprocessing prior to insertion of the additive noise. This suggests that the system of Figure 3 can potentially be generalized to allow for such preprocessing immediately following or prior to the first nonlinearity.

References

1. L.R. Rabiner, and R.W. Shafer, Digital Processing of Speech Signals, (Prentice-Hall 1978).

2. N.S. Jayant, "Digital Coding of Speech Waveforms: PCM, DPCM, and DM Quantizers", IEEE Proc. 62, 611-632 (1974).

3. B.M. Oliver, J.R. Pierce, and C.E. Shannon, "The Philosophy of PCM", Proc. of IRE 36, 1324-1331, (1949).

4. L.G. Roberts, "Picture Coding Using Pseudo-Random Noise," IRE Trans. Inform. Theory IT-8, 145-154 (1962).

5. L. Schuchman, "Dither Signals and their Effect on Quantization Noise", IEEE Trans. Commun. Tech. COM-12, 162-165 (1964).

6. L.R. Rabiner, and J.A. Johnson, "Perceptual Evaluation of the effects of Dither on Low Bit Rate PCM Systems", Bell Syst. Tech. J. 51, 1487-1494 (September 1972).

7. J.S. Lim, "Reduction of Quantization Noise in PCM Image Coding", Technical Note 1979-39, Lincoln Laboratory M.I.T. (1 May 1979).

8. J.S. Lim, and A.V. Oppenheim, "All-Pole Modeling of Degraded Speech", IEEE Trans. Acoust. Speech, and Signal Processing ASSP-26, 197-210, (1978).

9. J.S. Lim, "Enhancement and Bandwidth Compression of Noisy Speech by Estimation of Speech and its Model Parameters", M.I.T. Dept. of Elec. Eng. and Comp. Sci., ScD. thesis (August 1978).

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A new technique to reduce the effect of quantization noise in PCM speech coding is proposed. The procedure consists of using dither noise to ensure that the quantization errors can be modelled as additive signal independent noise and then reducing this noise through the use of a noise reduction system. The procedure is illustrated with examples.

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